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Opportunities of power-to-gas technology in different energy systems architectures

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HIGHLIGHTS

- Power-to-gas can provide energy storage for renewable energy storage.
- PtG can play different roles in different energy systems.
- PtG can support the transition of energy system toward sustainability.
- PtG can be an important source of renewable gases such as hydrogen, methane or SNG.

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ABSTRACT

This paper presents an overview of power-to-gas opportunities. Power-to-gas technology is gaining more and more popularity. It can provide large and long-term storage for increasing share of renewable sources in the energy system. In this paper, we would like to review the role of the power-to-gas system in different energy system architectures. Authors have analyzed the literature in the context of the problems, which could be solved by power-to-gas technology. Additionally, different assessment such as techno-economic, Life Cycle Assessment and Multi-criteria decision analysis for power-to-gas were revised.

1. Introduction

In order to face the challenges caused by climate change, the depletion of resources and the growing population, energy systems are being transformed all over the world to be more sustainable and to reduce the environmental impact. The future sustainable energy system is expected to based on clean and renewable energy sources, which should be able to provide constant and affordable access to electricity. The decision to transform the energy systems in the direction to increase the renewable energy share is due to some specific issues. The first one is the problem of greenhouse gases (GHG) emissions. The power sector is responsible for 25% of world GHG emissions [1]. Two more issues, which are also connected, are the population growth and the increase in electrical energy consumption. Nowadays, the 7.5 billion people living on the Earth [2], consume 20,000 TWh [3]. Recent studies estimate that the Earth's population can reach even 11.2 billion people in 2100 [4]. In this worst-case scenario, assuming constant energy consumption and considering that almost 2 billion people do not have access to a safe and secure supply of electricity, the worldwide electricity supply should double in the next 60 years. Of course, the amount of fossil fuels on the Earth is limited, so they should not be considered as an energy source at the end of this century. For these reasons, most countries are investing in renewable energy sources and energy-saving technologies.

In the EU the biggest push RES was provided by the Kyoto protocol, which was enforced in 2005 by imposing all old and new members to decrease the greenhouse gasses emissions. In 2007, the European Union leaders set the climate and energy package [5]. The key targets to be reached in 2020 in the EU aimed at 20% cut in greenhouse gas emissions (from 1990 level), 20% renewable energy production and 20% improvement in energy efficiency. The protocol was not considered sufficient and in 2015 new targets for lowering the emissions were set at the COP in Paris. The European decarbonization strategy set the target of 75% gross final energy consumption from renewable sources in 2050. This strategy also assumes decarbonization of transport and thermal energy for industry, services and buildings. The same document also states that natural gas will be critical for the transformation of energy systems [6]. All the above measures were not taken worldwide, and other regions and countries set different targets with different timing.

However, the time is showing that increasing the share of renewable energy production creates problems of electric grid operation and

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Nomenclature

AEC	alkaline electrolysis cell
CAPEX	capital expenditures
CCU	Carbon Capture and Utilization
COP	Conference of the Parties
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HTSE	High-Temperature Steam Electrolysis
LCA	Life Cycle Assessment
LNG	Liquefied Natural Gas
MCDA	Multiple-criteria decision analysis
MCFC	Molten Carbonate Fuel Cell
PEM	Proton Exchange Membrane
PtG	Power-to-Gas
PtM	Power-to-Methane
RES	Renewable Energy Sources
SNG	Substitute Natural Gas
SOEC	Solid Oxide Electrochemical Cell
VRE	Variable Renewable Energy

stability. The difficulty to predict accurately the energy supply causes challenges in electric grid management and electricity price volatility. Due to RES supporting policy, fossil-fired power plants are being switched-off and decommissioned and there is a strong need for novel solutions and technologies, which provide grid balancing and allow energy storage.

In this paper, we would like to discuss the opportunities offered by power-to-gas technology in balancing the grid and provision of energy storage. We believe that PtG technologies can solve the problems arising with the transformation of energy systems since it is possible to store the surplus between the supply and demand of electricity by transforming electric energy into a suitable carrier which can be later used as fuel in power plants to balance the surplus between the demand and renewable supply of electricity. Alternatively, since electric grids with 75% or more renewable energy production will need to have a large overcapacity of production. In such a case, it may be necessary to convert the surplus power to gas and not vice versa, and the produced fuel should be used for other energy uses such as in mobility and directly as thermal energy. In this paper, the role of power-to-gas in different system arrangements is also considered.

2. Power-to-x technology

General notation of systems, which convert electric power into another energy vector is denoted as power-to-x, where x is the final product of power conversion. Power-to-x, due to its modular structure, can

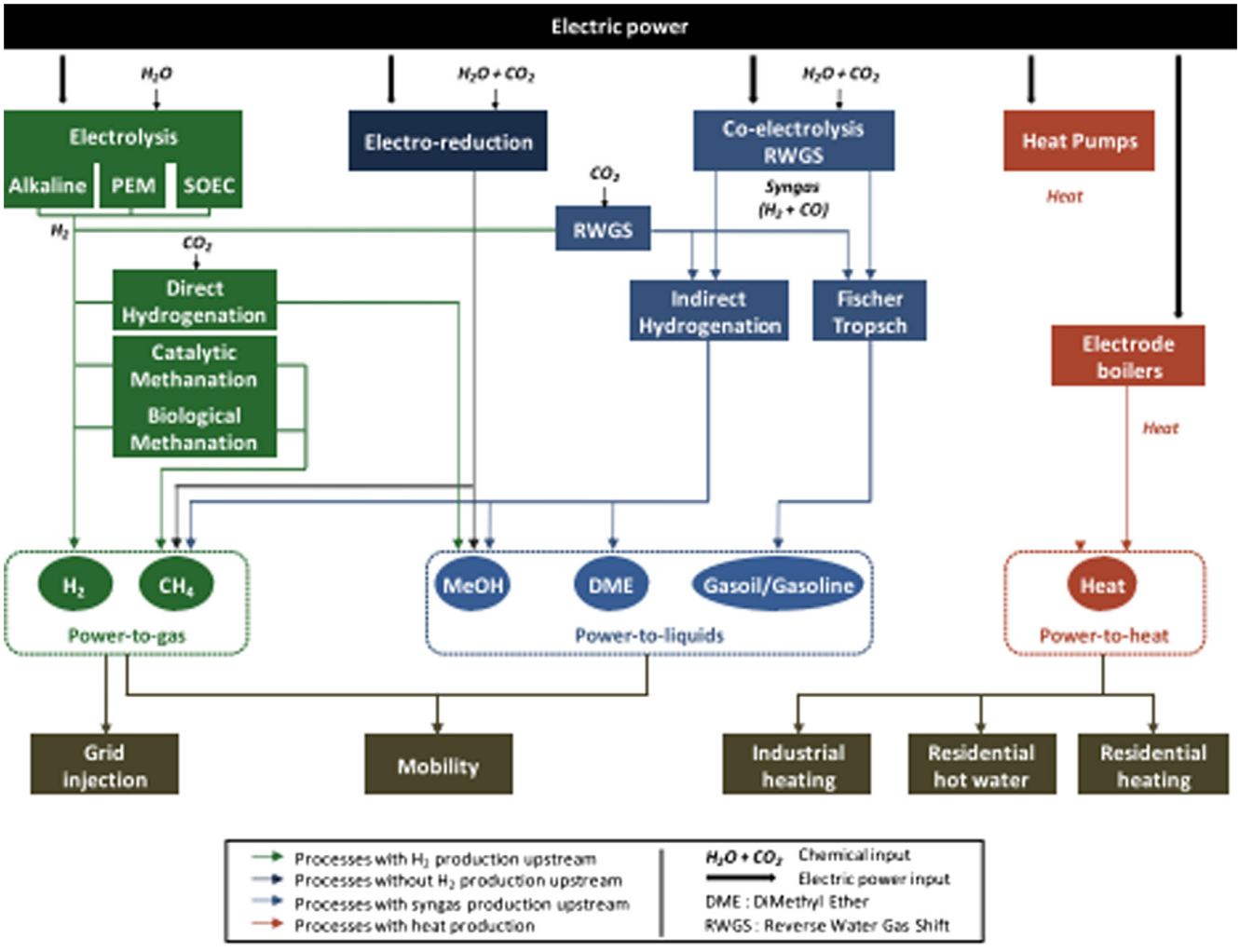

Fig. 1. Different power-to-x pathways; sources: [7].